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Second Quantization in Bit-String Physics*

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Abstract

Using a new fundamental theory based on bit-strings we derive a finite and discrete version of the solutions of the free one particle Dirac equation as segmented trajectories with steps of length h/mc along the forward and backward light cones executed at velocity $\pm c$. Interpreting the statistical fluctuations which cause the bends in these segmented trajectories as emission and absorption of radiation, these solutions are analagous to a fermion propagator in a second quantized theory. This allows us to interpret the mass parameter in the step length as the *physical* mass of the free particle. The radiation in interaction with it has the usual harmonic oscillator structure of a second quantized theory. We sketch how these free particle masses can be generated gravitationally using the *combinatorial hierarchy* sequence $(3, 10, 137, 2^{127} + 136)$, and some of the predictive consequences.

1 Bit-String Paths and Trajectories

Bit-String Physics, which we have also called *Discrete Physics*, [1, 2] grew out of the discovery of the *combinatorial hierarchy* by A.F. Parker-Rhodes in 1961. [3] A convenient introduction is provided by the Proceedings of the 9th meeting of the Alternative Natural Philosophy Association. [4] Recent work is summarized at the end of this paper.

In a technical sense, about all we need from the theory for this paper is the fact that we employ a universe of bit-strings generated by the algorithm called *program universe* in DP. Define a *bit-string* **a** containing W ordered bits by its sequentially ordered elements $a_w \in 0, 1, w \in 1, 2, 3, ..., W$, and its *Hamming measure* a by $a = \Sigma_{w=1}^{W} a_w := |\mathbf{a}(W)|$. Define *discrimination*, symbolized by "$\oplus$", between two bit-strings by the ordered elements $(a \oplus b)_w = (a_w - b_w)^2$; this is 1 when $a_w \neq b_w$ and 0 when $a_w = b_w$. Starting from a universe of strings of length W, all that program universe does is to pick two strings arbitrarily and discriminate them. If the result is non-null (i.e. the two strings differ), the discriminant is adjoined to the universe and the process begins again. If the two strings discriminate to the *null string* (i.e $0_w = 0$ for all w), we concatenate an arbitrary bit to the growing end of each string (i.e. $W \rightarrow W + 1$) and the process begins again.

We consider two strings **a**, **b** and their discriminant $\mathbf{a} \oplus \mathbf{b}$. Given no further information, we now show that the situation can be described by four integers which are invariant under any permutation of the ordering parameter w applied simultaneously to all three strings. Let n_{10} be the number of positions where $a_w = 1$, $b_w = 0$, n_{01} the number of positions where $a_w = 0$, $b_w = 1$, n_{11} the number of positions where $a_w = 1$, $b_w = 1$, and n_{00} the number of positions where $a_w = 0$, $b_w = 0$. Then

$$a = n_{10} + n_{11}; \;\; b = n_{01} + n_{11}; \;\; |\mathbf{a} \oplus \mathbf{b}| = n_{10} + n_{01} \tag{1}$$

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$$n_{10} + n_{01} + n_{11} + n_{00} = W \tag{2}$$

Note that the three non-null Hamming measures a, b, $|\mathbf{a} \oplus \mathbf{b}|$ are independent of both n_{00} and W. Only one of those two parameters can be chosen arbitrarily, subject to the constraint that $W \geq n_{10} + n_{01} + n_{11}$, or $n_{00} \geq 0$. It is the *independence* of our result from both string length and permutation of the order parameter which allows the statistics of the bit-strings generated by program universe to differ from the binomial distribution usually assigned to Bernoulli sequences, or "random walks".

The "random walk" with which we will be concerned is obtained from our more general model by defining a single, shorter string of length $n_{10} + n_{01}$ by $c_w = 1$ if $a_w = 1$, $b_w = 0$, and $c_w = 0$ if $a_w = 0$, $b_w = 1$. Then $r = n_{10}$ is the number of 1's and $\ell = n_{01}$ is the number of 0's in $\mathbf{c}(r + \ell)$, We now view this situation as describing the "motion" of a "particle" which is taking discrete steps of length h/mc in space and h/mc^2 in time at velocity $\pm c$ along the light cones. This is the starting point suggested by Feynman[5] and articulated, for example, by Jacobson and Schulman[6] for a derivation of the Dirac equation in 1+1 dimensions. If the particle is assumed to start at the origin $(0,0)$ in the x, ct plane, their boundary condition on the trajectories connecting two events at $(0,0)$ and (x, ct) is $x = (r - \ell)(h/mc)$, $ct = (r + \ell)(h/mc)$. We tie our model to this same space-time *trajectory*, but as noted above include an additional degree of freedom.

We now classify any string $\mathbf{c}$ by the number of *bends* $k(\mathbf{c})$, which counts the number of times a sequence of 1's changes to a sequence of 0's or visa versa. As McGoveran discovered,this number is simply computed from the elements of $\mathbf{c}$ by $k(\mathbf{c}) = \Sigma_{w=1}^{W-1}(c_{w+1} - c_w)^2$. We are interested here in the number of bends in the trajectory string of length $r + \ell = n_{10} + n_{01}$ These strings fall into four classes: RR, LL, RL and LR. For class RR the first and last steps are to the right; it has $k + 1$ right-moving segments, k left-moving segments and k bends; note that $k = 0$ corresponds to the forward light cone. Similarly LL has $k + 1$ left-moving segments, k right-moving segments and k bends. RL and LR cannot have $k = 0$ and have k right-moving segments, left-moving segments *and* bends. This classification is the same as in Jacobson and Schulman, but our statistical treatment is different.

In order to distinguish the connectivity we make between the two events from the space-time trajectories considered by Feynman, we call them *paths*. It is the interpretation of the additional two parameters n_{11} and n_{00} that allows us to extend our single particle treatment to an interpretation that has features in common with second quantized relativistic field theory. In the case of a *statistically causal* trajectory, time ticks ahead at a constant rate. If the particle does not take a step to the right, it *must* take a step to the left. Although our particle follows the same trajectory in space, if we encounter an example of w corresponding to either n_{11} or n_{00} it *does not move* in the single particle configuration space that is all the Feynman approach contains. We interpret this as representing background processes going on in program universe which do not directly affect the particle. In a second quantized relativistic field theory these "disconnected diagrams" are the first to be removed in a renormalization program. Although conceptually crucial to the way we count numbers of paths, they do not enter directly into our calculations.

Using light cone coordinates, a bend can be specified by any one of the r positions on the forward light cone and by any one of the ℓ positions on the backward light cone. However, because of the greater freedom in our string generation, there is no statistical correlation between them. There are r^k ways we can pick a position on the forward light cone and ℓ^k on the left. All we need do is insure that the restrictions imposed by the four classes of trajectories given above are met. Further, the order in which we make the choices is irrelevant, so we must divide each of these factors in the relative probability by $k!$. Since they are independent we must multiply $r^k/k!$ by $\ell^k/k!$ to get the (unnormalized) probability that both will occur in an ensemble of strings characterized by k bends and meeting our boundary conditions.

We conclude that the relative frequency of *paths* in the space of bit-strings of length $W > r + \ell$ which meet our space-time boundary conditions will have the values

$$P_k^{RL}(r,\ell) = [\frac{r^k}{k!}][\frac{\ell^k}{k!}] = P_k^{LR} \tag{3}$$

$$P_k^{RR}(r,\ell) = [\frac{r^{k+1}}{(k+1)!}][\frac{\ell^k}{k!}] \tag{4}$$

$$P_k^{LL}(r,\ell) = [\frac{r^k}{k!}][\frac{\ell^{k+1}}{(k+1)!}] \tag{5}$$

2 Formal Derivation of the Dirac Equation

Write the Dirac Equation in 1+1 dimensions with $h = 1 = c = 1 = m$ as

$$\psi_1 = (\partial/\partial t - \partial/\partial x)\psi_2;\ \psi_2 = -(\partial/\partial t + \partial/\partial x)\psi_1 \tag{6}$$

With $z^2 = t^2 - x^2 = 4r\ell$, this equation is solved by

$$\psi_1 = J_0(z) + \frac{2r}{z}J_1(z);\ \psi_2 = J_0(z) - \frac{2\ell}{z}J_1(z) \tag{7}$$

where J_0 and J_1 are the standard, real Bessel functions. We note that

$$J_0(z) = \Sigma_{j=0}(-1)^j(z/2)^{2j}/(j!)^2 = \Sigma_{j=0}(-1)^j[\frac{r^j}{j!}][\frac{\ell^j}{j!}] \tag{8}$$

Further

$$J_1 = -J_0' = \Sigma_{j=1}j(-1)^{j+1}(z/2)^{2j-1}/(j!)^2 \tag{9}$$

Hence

$$\frac{2r}{z}J_1 = \Sigma_{k=0}(-1)^k\frac{r^{k+1}}{k!}\frac{\ell^k}{k!} \tag{10}$$

$$\frac{2\ell}{z}J_1 = \Sigma_{k=0}(-1)^k\frac{r^k}{k!}\frac{\ell^{k+1}}{(k+1)!} \tag{11}$$

Since

$$J_1' = J_0 - \frac{1}{z}J_1 \tag{12}$$

we can now relate the solution of the differential equation to our relative frequency counts, as we now demonstrate.

We must now interpret the index 1, 2 in the Dirac equation, where it refers to the two spin-states, in the context of our bit-string model. We assume (since there is no coulomb interaction in the problem) that the bends in the trajectories correspond to the emission or absorption of a γ-ray, and hence to a spin flip. We connect ψ_1 and ψ_2 with the two (global) laboratory spin projection states and the four classes of trajectories as follows. Let ψ_1 correspond to correspond to the wave function for which the laboratory spin projection is $+\frac{1}{2}\hbar$. Consider first the RR trajectories with $k+1$ right moving segments k left moving segments and k bends. For k *even* the relative frequency of such trajectories is $P_k^{RR}(r,\ell) = [\frac{r^{k+1}}{(k+1)!}][\frac{\ell^k}{k!}]$ as we have already seen. Assume that the particle starts moving to the right with positive spin; since it experiences an even number of spin flips,it will have at the end points spin projection $+\frac{1}{2}$ as desired. However, if it started to the left with the same positive spin projection, it would have to take an odd number of bends to end up moving to the right. But then it has an odd number of spin-flips. Since what is conserved is *global* rather than local spin, these cases must be subtracted from the first to get the net number of relative cases with positive spin projection. Consequently, for these two classes taken together, the contribution to ψ_1 of trajectories which end with a step to the right is

$$\psi_1^R = \Sigma_{k=0}(-1)^k[\frac{r^{k+1}}{(k+1)!}][\frac{\ell^k}{k!}] = \frac{2r}{z}J_1(z) \tag{13}$$

Note that by including the $k = 0$ case we have normalized the sum to the forward light cone; this we can do because only relative frequencies and no absolute probabilities are involved.

Note also that *negative frequencies* simply mean that we have a preponderance of cases with the *wrong* helicity compared to that specified by the label. Similarly, if we construct the relative frequencies of trajectories which end up moving to the left and contribute to ψ_1 we find that

$$\psi_1^L = \Sigma_{k=0}(-1)^k[\frac{r^k}{k!}][\frac{\ell^k}{k!}] = J_0(z) \tag{14}$$

So

$$\psi_1 = \psi_1^R + \psi_1^L = J_0(s) + \frac{2r}{z}J_1(z). \tag{15}$$

Similarly

$$\psi_2 = \psi_2^R + \psi_2^L = J_0(s) - \frac{2\ell}{z}J_1(z). \tag{16}$$

Thus, *by imposing the spin projection conservation law* on our relative frequency counts, we arrive at the same formal expression that is obtained by the series solution of the free particle Dirac equation in 1+1 dimensions. Since, for either derivation, the truncation of the series is a practical necessity in any application to laboratory data, we have achieved our formal goal.

3 Second Quantized Interpretation

In our formal derivation, we avoided introducing a "free particle Hamiltonian"; we took our time evolution from the program universe generation of bit-strings. But the labeling of the two spin components ψ_1, ψ_2, was *ad hoc.* In a more detailed treatment, we would develop the spin, angular momentum, energy, momentum, and space-time discrete coordinates consistently from bit-strings. We will present this full discussion elsewhere. [7]

Here we must content ourselves with supplying a *label* to each of the three strings already invoked in our generation process. This can be simply the first two bits in the string. The system we model consists of fermions labeled by $\mathbf{f} = (10)$, antifermions $\bar{\mathbf{f}} = (01)$, and bosons $\mathbf{b} = (11)$. To these labels we concatenate bit-strings representing the propagation of the three types of particle in either space-time or momentum-energy space. The general connection between the three when there is an interaction, corresponding roughly to a vertex in a Feynman Diagram, is

$$\mathbf{f} \oplus \bar{\mathbf{f}} \oplus \mathbf{b} = \mathbf{0} \tag{17}$$

In this broader context, the single particle trajectory we have been following can be thought of as a particle moving forward in time or an antiparticle moving backward in time, and the two events as space-like rather than time-like separated. This replaces left-right motion in space with forward-backward motion in time, and the spin conservation we invoked with fermion number minus antifermion number conservation. This not only extends our derivation to the full x, ct plane rather than confining it to the forward light cone, but also shows that the single particle "wave functions" we derived have the appropriate CPT symmetry for use as basis functions in a second quantized relativistic field theory.

Once we have accepted this extended context, we can interpret the bends in the single particle trajectory we used above as due to the emission and absorption of quanta with probability $r^k/k!$, etc. Thus the bends in the trajectory are analagous to the states of the atoms in the walls of a black body enclosure invoked by Planck in his derivation of the black body spectrum. Because of the connection to radiation we have established (elsewhere) in our theory, the appearance of the usual statistical factor makes contact with conventional theory. Derivation of the usual connection between radiation states and harmonic oscillator models can proceed in a normal fashion. This was one reason for presenting this new result at this Workshop. Rather than go on translating familiar results into unfamiliar language, or visa versa, we hope you will find it of more interest to hear where this new approach to fundamental theory leads.

To conclude this section, we emphasis that *any* free particle which satisfies the Dirac equation can be thought of as interacting with the radiation background, while retaining the same mass. The fact that our space-time propagation comes from *program universe* rather than from a Hamiltonian allows us to remove the major "self-energy" contribution which occurs in a second quantized field theory by symmetry and equate it to zero. Once we include interactions, there will be finite changes in the effective mass, but no infinite mass renormalization. Our theory is "born renormalized". For us the mass in the free particle Dirac equation a finite first approximation of the *physical* mass; it is *not* the "infinite bare mass" of renormalization theory.

4 A New Fundamental Theory

"Bit-string physics" is a new, fundamental theory based on information theoretic concepts derived primarily from recent work in computer science. This theory has already achieved considerable conceptual clarity and quantitative success. In this section we present an outline of the underlying concepts and how they find physical application, following closely an earlier summary. [8]

We start from sequential counter firings with space interval $L \pm \Delta L$ and time interval $T \pm \Delta T$. We base our theory on invariant squared-intervals $c^2T^2 - L^2$ between counter firings. We model event intervals by *bit-strings* [i.e. finite ordered sequences of 0's and 1's] with N_1 1's and N_0 0's. We connect our model to laboratory events by taking $L = (N_1 - N_0)(h/mc)$, $T = (N_1 +$

$N_0)(h/mc^2)$. Calling any conceptual carrier of conserved quantum numbers between two distinct events a "particle", the velocity v of the particle is then given by $v = [(N_1 - N_0)/(N_1 + N_0)]c$.

If we now consider three counters, with associated clocks synchronized by limiting velocity signals, we can model the system by three bit-strings of the same length which add (using XOR, i.e. addition modulo 2) to the null string. The number of 1's in the strings satisfy the triangle inequalities, and hence can be used to define the angles between the lines connecting the counters. It also follows that the velocities as defined above satisfy the usual relativistic velocity addition law; this shows that our integer theory is "Lorentz invariant" for finite and discrete rotations and boosts. We prove that the usual position, momentum and angular momentum commutation relations follow from the fact that finite rotations in three dimensions do not commute.

In order to identify particles within the model we attach *labels* to the *content* strings which describe the (finite and discrete) space-time structure. Using 16 bits, the label gives us the 6 quarks, 3 neutrinos, $W^{\pm}, Z_0, \gamma$ and colored gluons of the standard model. Three strings which add to the null string map onto a Feynman diagram vertex. Baryon number, lepton number, charge and color are conserved; color is necessarily confined.

Mapping the $(2,4,16)$ decomposition of the labels onto $2^2 - 1 = 3$; $2^3 - 1 = 7$; $2^7 - 1 = 127$ we obtain the cumulative cardinals $(3, 10, 137)$, which are the first three levels of the four level *combinatorial hierarchy*, discovered by A.F. Parker-Rhodes in 1961. The first level describes chiral neutrinos, the second charged leptons and the third colored quarks. We justify the identification of the 137 as a first approximation to $\hbar c/e^2$ by correctly modeling the relativistic Bohr hydrogen atom, and improve on this result by deriving both the Sommerfeld formula and a logically consistent correction factor: $\hbar c/e^2 = 137/(1 - \frac{1}{30 \times 127}) = 137.0359\ 674$. [9] Weak-electromagnetic unification at the "tree level" comes about by using the same geometrical argument to calculate the electron mass in ratio to the proton mass either from the weak or the electromagnetic interaction and equating the two results. Predictions from the theory are given in Table I.

Extending our label length and mapping from 16 to 256 we get the fourth (terminal) cardinal of the *combinatorial hierarchy*: $2^{127} + 136 \approx 1.7 \times 10^{38} \approx \hbar c/Gm_p^2$, suggesting gravitational closure. Since we have baryon number conservation, we can consider an assemblage of nucleons and antinucleons with baryon number $+1$, charge $+e$, spin $\frac{1}{2}\hbar$ containing $N = \hbar c/Gm_p^2$ pairs with average separation $\hbar/m_pc$. Since the escape velocity for a massive particle from this assemblage exceeds c, it is gravitostatically stable against particle emission, but is unstable to energy loss due to Hawking radiation. Thanks to our baryon number conservation it ends up as a rotating, charged black hole with Beckenstein number $\hbar c/Gm_P^2$ [i.e. the number of bits of information lost in its formation [10]] which is indistinguishable from a (stable) proton. This extends Wheeler's "it from bit" [11] to particle physics. It *also* provides us with a *non-perturbative* mass scale relative to which mass ratios of particles which satisfy the free particle Dirac equation derived above can be measured.

Table I: **Coupling constants and mass ratios** predicted by the finite and discrete unification of quantum mechanics and relativity. Empirical Input: $c, \hbar$ and m_p as understood in the "Review of Particle Properties", Particle Data Group, *Physics Letters*, **B 239**, 12 April 1990.

COUPLING CONSTANTS

Coupling Constant	Calculated	Observed
$G^{-1}\frac{\hbar c}{m_p^2}$	$[2^{127}+136]\times[1-\frac{1}{3\cdot7\cdot10}] = 1.693\ 37\ldots\times10^{38}$	$[1.69358(21)\times10^{38}]$
$G_F m_p^2/\hbar c$	$[256^2\sqrt{2}]^{-1}\times[1-\frac{1}{3\cdot7}] = 1.02\ 758\ldots\times10^{-5}$	$[1.02\ 682(2)\times10^{-5}]$
$sin^2\theta_{Weak}$	$0.25[1-\frac{1}{3\cdot7}]^2 = 0.2267\ldots$	$[0.2259(46)]$
$\alpha^{-1}(m_e)$	$137\times[1-\frac{1}{30\times127}]^{-1} = 137.0359\ 674\ldots$	$[137.0359\ 895(61)]$
$G^2_{\pi N\overline{N}}$	$[(\frac{2M_N}{m_\pi})^2-1]^{\frac{1}{2}} = [195]^{\frac{1}{2}} = 13.96..$	[a] $[13,3(3),>13.9?]$

MASS RATIOS

Mass ratio	Calculated	Observed
m_p/m_e	$\frac{137\pi}{\frac{3}{14}\left(1+\frac{2}{7}+\frac{4}{49}\right)\frac{4}{5}} = 1836.15\ 1497\ldots$	$[1836.15\ 2701(37)]$
$m_\pi^{\pm}/m_e$	$275[1-\frac{2}{2\cdot3\cdot7\cdot7}] = 273.12\ 92\ldots$	$[273.12\ 67(4)]$
m_{π^0}/m_e	$274[1-\frac{3}{2\cdot3\cdot7\cdot2}] = 264.2\ 143\ldots$	$[264.1\ 373(6)]$
m_μ/m_e	$3\cdot7\cdot10[1-\frac{3}{3\cdot7\cdot10}] = 207$	$[206.768\ 26(13)]$

[a] [$G^2_{\pi N} = 13.3(3)$ from R.A.Arndt *et.al.*, *Phys. Rev. Lett.*, **65**, 157 (1990). F.Sammarruca and R.Machleit (*Bull. Amer. Phys. Soc.*, **36**, No. 4 (1991)) note most modern models for the nuclear force use the strong empirical ρ coupling and therefore require $G^2_{\pi N} > 13.9$; the smaller vector-meson-dominance-model value for ρ is compatible with the Arndt value.]

Table I. **Coupling constants and mass ratios** predicted by the finite and discrete unification of quantum mechanics and relativity. Empirical Input: $c, \hbar$ and m_p as understood in the "Review of Particle Properties", Particle Data Group, *Physics Letters*, **B 239**, 12 April 1990.

5 Fundamental Principles

The theory has grown from results that many physicists rejected as "numerological" to a framework that provides a consistent way to compute several fundamental constants of physical interest. It is based on fundamental principles that we believe should appeal to physicists who are sympathetic to the operational approach of Bridgman and the early work of Heisenberg. These principles are finiteness, discreteness, finite computability, absolute non-uniqueness [eg. In the absence of further information, all members of a (necessarily finite) collection must be given equal weight.] and our procedures must be strictly constructive. For us, the mathematics in which the Book of Nature is written is finite *and* discrete. We model nature by *context sensitive* bits of information. In this sense we are participant observers.

Physics, as a science of measurement, can expect that at least some of the structures uncovered in nature could result from the way we perform experiments. For example, Stillman Drake [12] has discovered that Galileo measured the ratio of the time it takes for a pendulum to swing to the vertical through a small arc to the time it takes a body to fall from rest through an equal distance as $948/850 = 1.108\ 2....$ We now compute this ratio as $\pi/2\sqrt{2} = 1.110\ 7....$ Thus Galileo *measured* this constant to about 0.3 % accuracy. [13] We now believe that this constant will be the same "anywhere that bodies fall and pendulums oscillate" independent of the units of length and time.

In any theory satisfying our principles which counts events by a single sequence of integers, any metric when extended to large counts can have at most *three* homogeneous and isotropic dimensions in our finite and discrete sense synchronized by one universal ordering operator. [14] More complex degrees of freedom, indirectly inferred to be present at "short distance" automatically "compactify". Hence we can expect to observe at most three absolutely conserved quantum numbers at macroscopic distances and times. Guided by current experience, we can take these to be lepton number, charge and baryon number, connected to the z-component of weak isospin by the extended Gell-Mann Nishijima rule. These are reflected in the experimentally uncontroverted stability of the proton, electron and electron-type neutrino. This choice is empirical but not arbitrary, since structures with appropriate conservation laws isomorphic with this interpretation arise in our construction.

Take the chiral neutrino as specifying two states with lepton number ± 1 and no charge. They couple to the neutral vector boson Z_0. In the absence of additional information, these states *close.* The 4 electron states couple to two helical gamma's and the coulomb interaction. These seven states can be generated by any 3-vertex which includes two electron states and an appropriate gamma. These $3 + 7 = 10$ states when considered together then generate the $W^{\pm}$. This completes the leptonic sector in the first generation of the standard model of quarks and leptons. Bit-strings of length 6 provide a compact representation of these states which *closes* under *discrimination* (exclusive-or), and conserves both lepton number and the z component of weak isospin at each vertex. No unobserved states are predicted at this level of complexity, and no observed states are missing.

Two flavors of quarks and three colored gluons provide the seven elements of the baryonic sector which generate the inferred 127 quark-antiquark, 3 quark, 3 antiquark, 8 gluon ... states (16 fermions times a color octet minus the state with no quantum numbers) needed for the "valence level" description of the quark model. Bit-strings of length 8 provide a compact model using seven *discriminately independent* basis strings and again close producing only the appropriate states at this level of complexity. Combining them with the leptonic states allows the strings representing the vector bosons to be extended to length 14, producing all the vertices and only the vertices which occur in the standard weak-electromagnetic unification of the first generation of the standard model. Extending the whole scheme to strings of length 16 we get the three generations which are observed experimentally (and a slot with the quantum numbers of the top quark). The quarks have baryon number 1/3 and charges $\pm 1/3, \pm 2/3$ as required. The $0 \leftrightarrow 1$ bit-string symmetry makes CPT invariance automatic. As already noted, if we have only three large distance quantum numbers, color (although conserved) is confined, and generation number is not conserved in flavor changing decays.

We are now in a position to talk about why we obtain the value of 137 in our first contact between the hierarchical structure generated by program universe and experimental numbers. *Empirically* only one of the 137 states required by the standard model of quarks and leptons corresponds to the coulomb interaction. Hence, by our principle of absolute non-uniqueness, the probability of this interaction occurring is 1/137 in the absence of further information.

Our basic quantum mechanical postulates are that (a) the square of the invariant interval between two events connected by a "particle" which carries conserved quantum numbers and conserved 3-momentum between them, is the product of two integers times $(h/mc)^2$ and that (b) space-like correlations for particle states with the same constant velocity can occur only an integer number n_λ of deBroglie wavelengths ($\lambda = h/p$) apart. These give us relativistic kinematics and the usual commutation relations for position, momentum and angular momentum.

If we model the hydrogen atom by events a distance r from a center we must have $n_\lambda \lambda = 2\pi r$. This interpretation is supported by noting that if the radius vector sweeps out equal areas in equal times, $\Delta A/\lambda^2 = (n_\lambda^2 - 1/4)(1/2\pi)^2$ and with $\ell = n_\lambda - 1/2$, the angular momentum is $\ell(\ell+1)\hbar^2$. Since these events occur with probability $1/137n_\lambda$, we get the relativistic Bohr formula [15] for the hydrogen spectrum. When we include a second degree of freedom, and take proper account of the ambiguities in counting, we get not only the Sommerfeld formula but the formula for α given above. Similarly, the fact that the basic Fermi interaction involves 16 possible states of four fermions gives us $\sqrt{2}G_F = (256m_p)^{-2}$ where the square root comes from the conventional interaction Lagrangian to which experimental numbers are compared, and m_p comes from the stability of the proton.

Our critics sometimes compare the constants we compute with a calculation of the dielectric constant of diamond as an analogy to how complicated the number $\hbar c/e^2$ must be from their point of view. We accept the challenge. When they assert that the dielectric constant of diamond can be calculated from first principles, they must assume that they already *know* a number of physical constants. Of course one can relate the standards of mass, length and time as measured in the laboratory to three dimensional constants (which could be $c, \hbar$ and G) that occur, self-consistently, in several structures derived from "first principles". But to get to diamond they will also need α, m_e, **and** M_C in well defined relation to those units, as well as the fact that the carbon nucleus has charge +6 in units of e. Otherwise their calculation has no potential empirical test.

We claim that within their framework, these three numbers are too complicated to calculate from first principles. In fact, when Weinberg discusses *how* a finite coupling constant might emerge from currently acceptable theory, his errors are so large that he cannot even contemplate a quantitative prediction that can be confronted by experiment. In contrast my values for α, and m_e are good to six or seven significant figures, and I can argue that my "first principles" allow me to predict that the common isotopes of carbon will have masses of approximately 12 and 13 proton masses. I have systematic ways of improving these estimates, and also— thanks to my physical cosmology — of estimating the relative abundance of these two isotopes on a terrestrial-type planet with an age of 4.5×10^9 years in a solar system of the kind in which we are conducting experiments. Somewhere along this line my calculation from "first principles" would find empirical supplements useful, but I believe no where near as soon as theirs.

I would locate the difference in point of view between us as coming from our different views of "space-time". If the "quantum vacuum" (which I would prefer to call a "quantum plenum") of renormalized second quantized relativistic field theory is the underlying concept, its properties certainly change as you "squeeze" it. The received wisdom today is that if the squeezing produces an energy density something like 10^{16} times that of the proton the "strong", "electromagnetic" and "weak" interactions come together (one basic "coupling constant" — grand unification) and that if one can extend the theory another three orders of magnitude, gravitation will find its appropriate place in the scheme. It seems to me that adopting "principles", however beautiful, that force one to go thirteen orders of magnitude beyond currently possible experimental tests to define fundamental parameters is — to say the least — a peculiar methodology for a physicist.

On the other hand, if one starts here and now with separated charges and massive particles and "empty" or "constructed" space as the first approximation, one can *measure* masses and coupling constants in a well defined way. If one can — as we claim — get good approximations for these values from "first principles" and systematically improve the predictions, I fail to see why such values cannot be considered "primordial". After the universe becomes optically thin, we predict about 2×10^{-10} baryons per photon. This both is in agreement with observation and supports our "empty space" philosophy.

6 Acknowledgements

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